Do Sophisticated Scientific Epistemological Beliefs Of Sri Lankan Senior Secondary Students Predict Their Conceptions Of Learning Science? A Structural Equation Modelling Analysis

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Abstract: This paper attempts to show the predictive effect of Sri lankan senior secondary students' scientific epistemological beliefs on their conceptions of learning science. The study was a survey using a sample which included 415 Sri lankan senior secondary students (grade 10 and 11).The structural equation modelling was performed to analyse the data to ascertain the predictive effect of scientific epistemological beliefs of these students. The results revealed that the senior secondary students' scientific epistemological beliefs predict their conceptions of learning science. Moreover it was found that sophisticated scientific epistemological beliefs of these students predict the constructive conceptions of learning science. The findings provide important implications for development of science curriculum and improvement of achievement level of senior secondary students in science.

Keywords: conceptions of learning, secondary education, scientific epistemological beliefs, science education

1. Introduction

In recent years, there has been an increasing interest in research related to epistemological beliefs and conceptions of learning. Epistemological beliefs are the beliefs regarding the nature of knowledge and knowing [1], [2]. Students' conceptions of learning are the views about their learning experiences and preferred ways of learning [3]. It has been found by several studies that these two concepts are interrelated [4], [5]. Further, some studies revealed that the beliefs of students and their conceptions are predictors of academic achievement. 'Epistemology' is an area of philosophy concerned with the nature and justification of human knowledge [1]. The personal epistemological development and epistemological beliefs are considered as psychologists' and educators' growing areas of interest [4], [6]. It is reported that these beliefs are connected to problem solving, conceptual change, learning strategies, reasoning modes, and decision making of students, when encountering a new situation [7]. The pioneering work to identify epistemological beliefs was performed by William Perry in 1990. He introduced epistemological beliefs as a core set of beliefs about knowledge and knowing that develop from simple and certain to complex and relativistic [4],[8]. Further he introduced a model with four stages of intellectual development. It includes dualism, multiplicity, relativistic and commitment within relativism. After Perry, there were many theories developed based on Perry's model. For example, Schommer in 1990, defined personal epistemology as a five-dimensional belief system that includes beliefs about "structure of knowledge", "certainty of knowledge", "source of knowledge", "control of knowledge" and "speed of knowledge acquisition"[8],[9]. Schommer's, structure of knowledge represents the views of knowledge and it composed of either isolated pieces to highly integrated concepts. The beliefs about certainty of knowledge includes students' beliefs about either certainty or tentativeness of knowledge. The beliefs regarding whether the knowledge is obtained from external authority such as teachers, text books, etc. or personal reasoning which is important for construction of knowledge are considered as "source of knowing". Moreover, "control of knowledge" contains beliefs regarding innate nature of learning or developmental nature of learning by time. The beliefs regarding whether learning occurs quickly or gradually are included in "speed of knowledge acquisition" [9]. After Schommer, Hofer and Pintrich (1997) have suggested four dimensions of epistemological beliefs based on Perry's and Schommer's models. These dimensions are; "certainty of knowledge" (stability), "development of knowledge" (structure), "source of knowing" (authority), and "justification of knowing" (evaluation of knowledge claims). The first two dimensions are considered as the beliefs related to the nature of knowledge while the latter two dimensions are the beliefs associated with the nature of knowing [1],[8].The questionnaire named 'Scientific epistemological beliefs (SEB) survey' was developed in 2004 by Conley and others for a large sample of students. It includes four dimensions, that are, source, certainty, development and justification [10]. It was the tool most commonly used in studies to assess scientific epistemological beliefs both in students and teacher students. All these dimensions were basically consistent with Hofer and Pintrich's four general epistemological dimensions. Conversely, these dimensions have been related to the context of science learning by Conley et al (2004).This questionnaire has been first used to study elementary or high school students' SEBs [3]. Items under each dimensions are created in such a way that students are asked about how they believe in knowledge and knowing using simple statements. It has been found that epistemological beliefs are strong predictors of students' cognitive performances and affective responses[8],[11]. Similarly, several studies have revealed that there is a significant relationship between epistemological beliefs and academic achievement [12], [13]. As such, epistemological beliefs are considered as an important internal factors that drive student for an effective learning Individuals develop conceptions about the nature of their learning and these conceptions are crucial in a range of learning and teaching experiences [14]. Students view learning process through the lenses of conceptions and behave accordingly. Recently, certain studies have focused on the conceptions of learning for a specific knowledge domains, such as for science, biology and mathematics. The learning environment created by the science teacher also plays a role in shaping students' perceptions on the way they practice science and created new knowledge [15]. Marton and Saljo in 1979 [16] carried out a pioneering study about the conceptions of learning by conducting interview with 90 individuals for asking the meaning of learning for them. He found that, individuals had five different conceptions of learning. These were "increase of knowledge", "memorizing', "the acquisition of facts, procedures etc" which could be retained and/or utilized in practice, "abstraction of meaning", "interpretative process aiming at an understanding of reality" [14],[17]. After Saljo's study, several researchers studied on different groups of individuals and different contexts to categorize conceptions of learning [10]. Tsai in 2004 interviewed 120 Taiwanese high school students to explore conceptions of learning science. The framework which was proposed included seven categories:

1. "learning science as memorizing,"
2. "learning science as preparing for test,"
3. "learning science as calculating and practicing tutorial problems,"
4. "learning science as the increase of knowledge,"
5. "learning science as applying,"
6. "learning science as understanding,"
7. "learning science as seeing in a new way."

Above categories are sequenced in a hierarchical framework, from lower level to higher-level which indicates the shifting from traditional to constructivist conception on learning. The Conceptions of Learning Science (COLS) questionnaire was constructed by Lee and others in 2008 to investigate high school students' conceptions of learning in Taiwan [17]. It was based on the study of Tsai (2004) and included aforementioned seven factors [18], [10]. Instead the conceptions of learning can be identified as two types, constructive (higher level) conceptions and reproductive (lower level) conceptions. Three categories of conceptions namely 'memorizing', 'testing', 'calculate and practice' were considered as reproductive conceptions of learning while other four conceptions namely 'increase of knowledge', 'applying', and 'understanding' and 'seeing in new way' were considered as constructivist conceptions of learning [10]. These conceptions of students on learning reflects the teaching approach of teachers and learning environment of the classroom Several studies have been conducted to explore the relationship between epistemological beliefs and learning conceptions. A study was conducted by Liang &Tsai (2010) to investigate the relationship between scientific epistemological beliefs and conceptions of learning science in college science-major students in Taiwan. The results indicated that the sophistication of SEBs was consistent with less agreement to lower-level or reproductive COLS while more agreement with higher- level COLS or constructive COLS. Conversely, the SEB's "justification" factor was positively related to almost all of COLS factors from the lower-level to higher-level [3]. Another study related to biology learning of high school students has been undertaken by Sadi & Dagyar (2014) to examine the relationships among epistemological beliefs, conceptions of learning, and self-efficacy. It was revealed that the students' epistemological beliefs about the source/certainty, justification, and development of biology knowledge have some direct and positive relations with some factors of conceptions of learning [2]. Moreover, another study aimed to explore the relationships among Taiwanese high school students' SEBs, COLS and motivation of learning science was undertaken by Ho & Liang (2015) [19]. The findings revealed that these students' absolutist SEBs were related to reproductive COLS while sophisticated SEBs were related to constructive COLS. Nevertheless, to the authors'´ best knowledge, very few publications are available in the literature that address student related cognitive factors such as epistemological beliefs and learning conceptions of Sri Lankan students. It indicates the less attention paid by researchers and educationists in Sri lanka on these student related cognitive factors. In fact, it is reported that the Sri Lankan students are more exam oriented and they have become over dependent on rot learning [20], [21]. Rot learning discourages the development of constructive conceptions. Despite that, as many other countries, there is a high demand for science and technology skills due to the structural changes that are taking place in the economy [22]. In this context, students with abilities such as analytical thinking, ability to develop relationship and ability to use scientific methods to solve problems are required for the country. However, it is vital to state that the achievement rate of Sri lankan senior secondary students in grade 10 and grade 11 leading to General Certificate of Ordinary Level Examination, for the subject science is considered to be unsatisfactory. According to National Education Policy strategic plans, which was aimed to be implemented from 2012 to 2016 in order to enhance the quality of science education in Sri lanka, one of the objectives was to increase the pass rate of science at senior secondary level up to 80% by 2016. Besides several intervention programs to improve this achievement rate, still the expected trend of improvement is not indicated by the examination results [23]. In Sri lanka the school curriculum is reformed in every 7 years and a competency based curriculum has been introduced in order to enhance the quality of school education by promoting constructive learning environment in class rooms. Besides these reforms still the class room learning-teaching process is dominated by teacher centered lecture method which direct the learners for rot learning. Moreover, researchers emphasized that if the epistemological belief systems of students is ignored, it can lead to ineffective teaching strategies and poor learning outcomes [24]. Further, if the teaching-learning process for science becomes a trend of rote memorization, not only the pedagogical danger but also there would be an epistemological danger in which science is viewed as a body of absolute facts or received knowledge [25, 26]. Hence, if the problem situation of low achievement level of students for science in Sri lanka continues, there might be a greater risk of resulting future generation with poor scientific and innovative skills. Some previous studies provide evidences for the fact that the constructive conceptions of students directs them for meaningful learning and these conceptions can be developed by sophisticated epistemological beliefs. Thus, the present study aimed to find if Sri lankan secondary students' epistemological beliefs predict their conception of learning science. Identification of such a relationship would help to understand students' learning process and to provide implications to classroom teaching [5]. Thus such studies are timely needed and contribute not only to improve the achievement rate but also to strengthen the students with scientific and innovative skills. Furthermore, the findings of this study will contribute to improve the science curriculum by giving special attention to these psychological factors.

2. Method

2.1. Participants

The sample included 415 secondary students (leading to General Certificate of Ordinary Level) from government schools in Western Province of Sri Lanka. Western Province represents comparatively highest number of senior secondary students (117,157) and it is nearly one third (28.4%) of total number of secondary Students in Sri lanka. Further it represents all school types of Sri Lanka. Stratified proportionate sampling was applied to select schools from each district and then from each school type. Students were selected from classes in each school using simple random sampling method. The sample is represented by 38.9 % male students and 61.1% female students. Considering the grade level, 47.6% of students was in Grade 10 and 52.4% of students in Grade 11.

2.2. Instruments

Scientific epistemological beliefs of students were measured using SEB questionnaire developed by Conley and others in 2004 [27] and conceptions of learning science were assessed by COLS questionnaire developed by Lee and others in 2008 [17]. These questionnaires were translated into Sinhala language using translate and back-translate method. Both questionnaires were designed to be rated by 5-point Likert type scale, from ‘strongly disagree’ (1) to ‘strongly agree’ (5). Since the “source” and “certainty” dimensions reflects less sophisticated beliefs, the responses for “source” and “certainty” dimensions were reverse coded (5- strongly disagree to 1-strongly agree) in order to obtain higher scores for more sophisticated beliefs.

2.3. Data Analysis and Procedures

The Structural Equation Modelling by Partial Least Square (PLS-SEM) method was performed to analyse the measurement model and structural model using SmartPLS. SEM approach was used as it enables the researcher to analyse the relationships between several latent variables simultaneously.

3. Results

3.1. Analysis of the Measurement Model

The analysis of the measurement model of the study included the analysis of internal consistency reliability, the convergent validity and discriminant validity of the constructs. The accepted value for composite reliability and Chronbach’s alpha is the greater value of 0.7 [28]. In the present study composite reliability as well as Cronbach’s alpha values of all items were above 0.7 which indicates the internal consistency reliability of all the constructs (Table 1).

Table 1. *The quality criteria of measurement model*

Construct	AVE	Composite Reliability	Cronbachs Alpha
Source of knowing	0.56	0.8631	0.80
Certainty of Knowledge	0.55	0.8266	0.75
Development of knowledge	0.60	0.9013	0.87
Justification of Knowing	0.57	0.9219	0.90
Reproductive conceptions	0.45	0.9051	0.88
Constructive conceptions	0.44	0.8736	0.84

The convergent validity is the extent to which a measure correlates positively with alternative measures of the same construct and it is established by the average variance extracted (AVE). Moreover, AVE is the degree to which a latent construct explains the variance of its indicators. AVE value of 0.50 or higher indicates that, on average, the construct explains more than half of the variance of its indicators. Generally, indicators with outer loadings between 0.40 and 0. 70 should be considered for removal from the scale only if the removing the indicator leads to an increase in the composite reliability and AVE [28] (Hair et al, 2014). In the present study outer loadings for 3 indicators were between 0.4 and 0.7 and removal of them resulted in increased AVE (AVE>0.5). As can be seen in Table 1 the AVE value for all the construct were greater than 0.5 which confirmed convergent validity. The extent to which a construct is truly distinct from other constructs, in terms of how much it correlates with other constructs is known as discriminant validity. It was determined by obtaining cross loadings (outer loadings on other constructs) of indicators. The outer loadings on the associated constructs were greater than all of its cross loadings which is considered as a criteria to be satisfied in order to get the discriminant validity [28] (Hair et al, 2014). Hence, it can be considered that the discriminant validity of the constructs of present study was confirmed.

3.2. The Structural Model

The relationships of the structural model is determined by path coefficients which represent the hypothesized relationships among the constructs. The path coefficient (Beta value) indicates the extent to which the exogenous construct is associated with the endogenous construct. However the significance of the association is determined by t-statistics which is calculated by bootstrapping with 5000 re-sampling as suggested by Hair et al. (2014). Significance of associations is indicated by the critical values for a two-tailed test that are, 1.65 (significance level = 10%), 1.96 (significance level = 5%), and 2.57 (significance level = 1 %) [28]. The T statistics of the respective hypothesis and the beta value are shown in Table 3. Based on hypothesis testing, all the beliefs were positively related to constructive conceptions. It explains that sophisticated scientific epistemological beliefs have predicted constructive conceptions for learning science. In addition, source of knowing and development of knowledge have shown a negative relationship with the reproductive conceptions. The beliefs about source of knowing had a greater effect (p=0.78) on the prediction of constructive conceptions than other beliefs.

Table 3. *Significant Testing Results of the Structural Model Path Coefficients*

Hypothesis	Path Coefficient (p)	T Statistics
Source →Constructive conceptions	0.78	24.19***
Source → Reproductive conceptions	-0.89	39.46***
Certainty →Constructive conceptions	0.10	3.03***
Certainty →Reproductive conceptions	0.02	0.62
Development→ Constructive conceptions	0.08	2.14**
Development →Reproductive conceptions	-0.07	2.26**
Justification →Constructive conceptions	0.09	2.64***
Justification → Reproductive conceptions	0.06	1.49

** p<0.1 **p<0.05 ***p<0.01; SK-Source of Knowledge; CK-Certainty of Knowledge, DK-Development of Knowledge; JK-Justification of Knowing*

4. Discussion

The results of the study revealed that Sri Lankan senior secondary students' sophisticated epistemological beliefs predict their constructive conceptions of learning science. The finding explains that when students' beliefs about the source of knowing become sophisticated (from the belief "science knowledge resides in external authority" towards the beliefs "science knowledge can be actively constructed by the knower"), they tended to hold more constructive conceptions such as "science learning is understanding, applying knowledge and seeing in new way". Along the similar line, past studies revealed that the beliefs about source of knowing has a positive relationship with constructive conceptions [4]. Similarly Students' conceptions of learning science have become more constructive with the sophistication of beliefs about certainty of knowledge in which they believe science knowledge is not certain or absolute but tentative. Results further showed that the sophisticated beliefs related to development of knowledge have also predicted constructive conceptions of students. When learners believe science as an evolving and changing subject, their conceptions of learning were appeared to be constructive such as view the learning as increasing and applying knowledge, understanding and seeing in new way. Senior secondary students' constructive conceptions were further predicted by the sophisticated beliefs about justification of knowing. It explains that the students who believe science learning as try out experiments and confirm the knowledge were found to be developed constructive conceptions such as understanding, applying the knowledge, seeing in new way. On the contrary, the beliefs about source of knowing and development of knowing have negatively predicted reproductive conceptions of senior secondary students. It indicates that with the sophistication of the beliefs about knowledge development (believing the science knowledge as an evolving and changing subject), students conceptions become less reproductive (not conceiving science learning as memorizing, testing and calculating). The negative relationship between the beliefs about source of knowing and reproductive conceptions explains that with the sophistication of beliefs about development of knowledge which reflect students' agreement for believing the knowledge as something self-constructed or cannot always be gained from external authority , the lesser the development of reproductive conceptions such as memorizing, testing and calculating. The R square (R)) value or the coefficient of determination value is critical for evaluating a structural model which indicates the exogenous latent variables' combined effects on the endogenous latent variable It is considered as substantial if R2 ≥ 0.75, moderate if R2 ≥ 0.50 and weak if R2 ≥ 0.25. [28]. As such, the structural model of the present study shows moderate level explaining power for the endogenous variables reproductive conceptions (R2=0.74) and constructive conceptions (R^2=0.60). As such, there was a moderate combine effect of variables of SEB on the endogenous variables; reproductive and constructive conceptions.

5. Conclusion

The present study revealed that the senior secondary students' scientific epistemological beliefs predict their conceptions of learning science. Overall, the results showed that with the advancement of these beliefs towards sophistication, students tended to develop constructive conceptions. In contrast, with holding less sophisticated and naïve beliefs about source of knowing and development of knowledge, they have become more inclined to develop reproductive conceptions of learning science. It parallels the recent study on Taiwan College students in relation to biology learning which revealed the relationship between scientific epistemological beliefs and conceptions of learning [4] The findings provide implications to curriculum development and improvement of achievement level of students for the subject science. Further, this the study contributes to knowledge required for the education system including educationists, educational researchers and curriculum developers about the relationship of secondary students' scientific epistemological beliefs and their conceptions of learning science. Teachers can be aware of these findings and motivated to establish a constructive class room environment through developing sophisticated scientific epistemological beliefs. Effective lessons and activities can be integrated to the curriculum of teacher training courses in training colleges for guiding student-teachers to develop sophisticated beliefs. Teacher trainers can organize training programs addressing the importance of the relationship between scientific epistemological beliefs. The study further contributes to improve the assessment & evaluation methods in order to discourage the rot learning style of students. Similarly it contributes to provide an awareness for policy makers who take policy decisions regarding intervention programs to enhance the achievement of senior secondary students for the subject science. Overall, this paper provides a greater evidence for the importance of the relationship between students' scientific epistemological beliefs and their conceptions of learning science.

Author Profile

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